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Risk Assessment and Optimization of China's Oil Imports Structure

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Abstract

Stability of energy supply is very important for importing countries. The disruption in external supply sources could have an exceptionally negative impact. To counter this threat, importers attach to diversify risk by optimizing import structure. Existing research is accustomed to classifying risks into systemic risks and specific risks. Among them, systemic risk refers to the volatility of the oil market, which is mainly related to oil prices. Specific risk refers to the disruption risk in oil-producing countries. So, there is a question, does it make sense to incorporate systemic risk into the model when optimizing the import structure?

Keywords

Oil Supply Disruption; Oil Price Volatility; Import Portfolio.

1. Introduction

Energy security has been a hot topic in recent years. It has been defined and measured in many different ways. It is also found that concerns and perception of energy security have been changing over time. But there is a common view among the different definitions that energy security is ensuring continuity and maintaining supply at affordable prices.

It is more important to ensure a stable energy supply for energy importing country. However, As the largest country in oil consumption, China's energy security level is not optimistic. On the one hand, the domestic oil supply cannot satisfy the increasing demand, more than 70% of the oil consumption is imported. On the other hand, the most sources of China's oil imports are from the Middle East. Which political turmoil and frequent wars means high level supply disruption risks. In addition, the importing oil is mostly transported by tankers, and passing through dangerous areas such as the Strait of Malacca. All those factors pose a threat to China's energy security. There for, assessing the disruption risk and optimizing the import strategy to reduce China's energy import risk has great significance.

A challenging problem for researchers and analysts is how can energy security be quantified and be made useful for policymaking. An approach to addressing this issue is through the use of indicators and the construction of energy security indexes from these indicators. There are many studies which propose indicators and indexes to measure the energy security of a single country. Scholars have selected evaluation indicators from different perspectives. Sun et al. (2014) quantifies the risk of China's oil imports from the perspective of China's oil supply and demand from two aspects: country risk and transportation risk. Sun et al. (2017) proposed a risk quantification model from the perspective of oil supply chain, this paper quantified oil supply risk from four aspects: exporting country, transportation, importing country and economic environment, and using China's oil import data for empirical test, the results show that China has different risks during different stages. Yang et al. (2014) measured external oil supply risks by considering two aspects of country risk and potential oil export capacity, and selected four major importing countries, China, Japan, the United States, and Europe as samples,

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and found that the country risk of oil supplying countries affects the security of external oil supply, China's import strategy needs to shift to an exporter with high potential export capacity as oil demand grows.

Another critical approach, portfolio theory, has been most frequently used to explore the aggregate risk of a portfolio of importers (Lesbirel 2004). The extent to which diversification reduces supply risk depends on the nature of the market and political relationships between the supply sources. Lesbirel (2004) highlighted this using the example of price changes as a measure of risk and considering how diversification can reduce risks given different covariances between the costs of imports. Wu et al. (2007) and (2009) applied the approach to a China case, in which both systematic and specific risks are concerned.

We found that the main difference in the selection of indicators for import risk assessment is whether to consider the impact of oil price, that is, the systemic risks. In recent years, the oil price fluctuated severely, which has a serious negative impact on the economy of importing and exporting countries, and even caused a serious oil crisis. Therefore, this study put oil price into the risk evaluation model, and then optimize the import strategy use Markowitz investment model. At last, Contrasting the different between whether to consider the systemic risk on import optimization.

In the following, we introduce the method in section 2, which mainly focuses on the measurement of import risk and the optimization of import strategy. Section 3 describes the data and sources. And we discuss the results and provide policy suggestion in Section 4.

2. Methodology

This paper optimizes the import strategy on the basis of import risk. Therefore, we introduce the method into two parts: Risk assessment and import strategy optimization.

2.1. Risk Assessment Model

2.1.1. Disruption Risk Indicator: Country Risk

For oil-exporting countries, country risk objectively reflects the whole national risk status and reflects the stability of oil supply. country risks of oil exporting countries are naturally introduced to describe the whole risk exposure of oil imports. Specifically, because country risk is determined by country specific and regional economic, financial and political risk factors and some other composite factors, its volatility may cause decrease of energy supply and even stop oil importers from getting a reliable and stable oil supply. Therefore, many scholars consider the indicator of country risk in previous research. (Li et al. 2014, Sun et al. 2017, Kim & Kim 2018). In this paper, we use the International Country Risk Guide (ICRG) compiled by PRS as the country risk index. The International Country Risk Guide (ICRG) rating comprises 22 variables in three subcategories of risk: political, financial, and economic. which is a value between 1 and 100. Therefore, the country risk of an oil supplier can be shown as follows:

$$CR_{it} = (100 - ICRG) \quad (1)$$

Where CR_{it} stands for the overall country risk of oil supplier i in year t.

2.1.2. Disruption Risk Indicator: Transport Risk

Tankers and pipelines are the main modes of transport used to import oil into China. China's five shipping routes are Middle East Route, North Africa Route, West & Southern Africa Route, South America Route and Asia Pacific Route. Oil pipeline transport channels in China include the China–Kazakhstan pipeline, China–Russia crude oil pipeline and China–Myanmar crude oil pipeline which alleviate China's dependence on shipping transport (sun et.al 2014). Pipeline risk mainly from the important nodes on the route, such as the Malacca Straits and Hormuz Straits, the probability of pirate attacks related to transportation safety closely. Therefore, we use the same method as Guo et al. (2020) and make the average number of attacks of each node to the total number of attacks per year to express the risk of each node. The calculation method detailed in Wu et al. (2009). And then, converting it into the probability of being attacked on the transportation route according to the following method.

$$P_{it} = \sum_{v=1}^{n} p_{vt} \prod_{m=1}^{n} (1 - p_{mt}) \tag{2}$$

Where P_{it} represents the probability of v^{th} node disrupting in the transportation route from exporting country i to importing country in year t. 1-p_{mt} represent the probability of safety node m in the transportation route. In particular, m and v are different nodes on the rode through exporter i to importer j , and m $\neq v$.

2.1.3. Disruption Risk Indicator: Export Ability

Supply capacity of oil-producing countries is also one of the important factors that cause sudden supply shortages. Various reasons such as war, economic turmoil, and investment in exploration may lead to a decline in production capacity, and the export share can directly reflect its supply ability. In 2019, the world's largest oil company, Aramco, suffered an air strike and its production capacity reduced by 50%, which directly led to a 2.8% drop in Saudi oil exports share compared with 2018. The reserve-production ratio refers to the time that the proven reserves of an oil-producing country can be maintained at the current production level, which can reflect the country's long-term export capacity. Base on this, we refer to the methods of Yang et.al (2014) and Wang et.al (2018), selecting the ratio of reserves to production and the share of exports in the world's total exports as indicators to measure the export capacity of oil-producing countries. This method considers both long-term and short-term factors.

$$ER_{jt} = r_{jt} * s_{jt} \tag{3}$$

Where ER_{jt} stand for the export capacity, r_{jt} is the Reserve-production ratio and s_{jt} is the share of country j in total world exports in year t.

2.1.4. Disruption Risk Indicator: Relationship Risk

The relations of an importer with its exporter would have a significant impact on its supply security. Li Zhongda, et al. (2019) proposed that for each level of diplomatic relations, China's openness to other countries' goods increased by 23%, and friendly diplomatic relations had a promoting effect on international trade. On the other hand, the Institute of World Economics and Politics (IWEP) and the Chinese Academy of Social Sciences takes trade dependence as one of the evaluation indicators for relations with China. It can be seen that there is a mutual promotion between the international relations and the bilateral trade. In this study, we refer to the method of Li Zhongda, et al. (2019) which take diplomatic relations as one of the risk indicators for evaluating bilateral relations.

2.1.5. Market Risk Indicators

Oil price is one of the important indicators reflecting the volatility level of the oil market. China as largest oil importer, rising oil prices directly lead to the increase of production cost and wealth transfer, which has a negative impact on the economy (Hamilton, 2003; Muellbauer & Nunziata, 2001). In addition, Paul Cashin (2014) pointed out that the impact of oil price fluctuation is no obvious difference between countries, Oil importing and exporting countries are all facing long-term inflationary pressure, real output increases and stock prices fall. It can be seen that the impact of oil price fluctuations on economic cannot be ignored. Based on this, this paper uses oil price volatility to represent the level of market risk. In addition, for large oil-producing countries, the oil industry is one of the main economic incomes. So, higher export share means the greater exposure to risk fluctuations in the oil market. Therefore, in this study, the measurement indicators of market volatility risk are set as follows.

$$MR_{it} = Var^{P} * S_i^t \tag{4}$$

Where S_i^t Indicates the global export share of oil-producing country i in year t, $Var^P = (P_t - P_{t-1})/P_t$.

2.2. Comprehensive Risk Evaluation

The main purpose of this study is to discuss whether it is necessary to consider oil price volatility as market risk on the optimization of oil import strategies. Therefore, we divide the risk into two situations: disruption risk and comprehensive risk. In this paper, disruption risk is calculated by the TOPSIS evaluation method, which converts different indicators into a unified type. And comprehensive risk is based on the disruption risk which considering market risk in access system. Those two risks can be expressed as follows:

Disruption risk:

$$r_1 = f(CR_{it}, P_{it}, ER_{jt}, MR_{it}) \tag{5}$$

Comprehensive risk:

$$r_2 = w_1 r_1 * w_2 MR_{it} \tag{6}$$

Where w_1 and w_2 represent the weights of disruption risk and market risk respectively. They represent which risk are more concerned by decision makers. We set w_1 and w_2 equal to 0.5 in this paper. The detailed calculation of disruption risk is presented in appendix.

2.3. Risk Optimization Model

This paper uses the Markowitz portfolio to adjust the import structure and optimize the import risk. The model considers the balance between risk value and risk volatility, and aims at risk minimization to obtain the optimal import portfolio. In addition, to ensure the diversity of import sources, we set the following constraints: for any oil-producing country i, the optimized import share should be between the maximum and minimum value of the actual import share. Under the above conditions, the basic equation can be set as follow.

$$min(\sigma^2) = \sum_{i=1}^{\mathrm{N}} \sum_{j=1}^{\mathrm{N}} w^{(i)} w^{(j)} \sigma_{ij} \tag{7}$$

s.t.

$$\begin{cases} \sum_{i=1}^{\mathrm{N}} w^{(i)} r_i = E(r) \\ \sum_{i=1}^{N} w^{(i)} = 1 \\ w^{(i)} \geq 0, \forall K \epsilon [1,2,3 \dots N) \\ S_i^{min} \leq w^{(i)} \leq S_i^{max} \end{cases}$$

where $w^{(i)}$ and $w^{(j)}$ are the import shares of different supplier i and j, σ_{ij} is the covariance coefficient between risks. S_i^{min} and S_i^{max} are the maximum and minimum values of historic import share of source i.

According to the above model, we use MATLAB to get an efficient frontier, and all the import portfolios on the frontier satisfy the optimal portfolio under the given risk level. After determining the efficient frontier, we obtain the final import portfolio through a utility function. This function is used to represent decision makers' aversion of risk volatility in different situations. It is expressed as follows:

$$max\ U = E(r) - \frac{1}{2}A(\sigma^2) \tag{8}$$

Where U is the utility value and A is the risk volatility aversion index of the decision maker. A > 3 means greater risk aversion and A < 3 means less risk aversion. In this paper, A = 3 is used as the base scenario to solve the optimal portfolio of oil imports.

3. Data Source and Pre-processing

China is the largest oil consumer and importer, and its main sources of oil are Saudi Arabia, Russia, Angola, Iran, Iraq, Oman, and Brazil from 2005 to 2019. Therefore, we select those 7 countries as the evaluation objects, collecting the necessary data and accessing the disruption risk, comprehensive risk, and the desire Import Portfolio optimize by those two different risks. Before accessing the comprehensive risk, there is a need to pre-process the data by normalization. An improved normalization method is provided as follows:

$$Z_{ij} = 0.1 + 0.9(maxr_j - r_{ij})/(maxr_j - minr_j), i \in 1, \dots, n \tag{9}$$

Where $\boldsymbol{r_{ij}}$ represent the risk matrix, i is different exporting countries, j is the above risk factors.

4. Results and Discussion

This section describes the risk level of China's oil import source countries from two aspects: disruption risk and comprehensive risk.

4.1. Disruption Risk and Comprehensive Risk

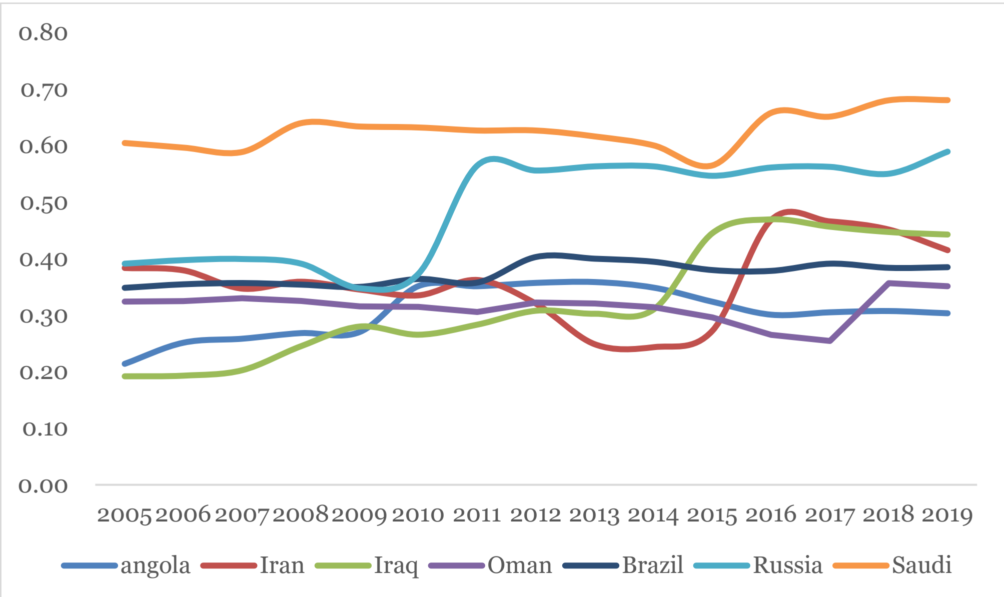

Fig 1. The disruption risks of different source

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Fig 1 shows the disruption risk of China's importing source, the lower values indicate higher level of disruption risks. It can be seen that, Saudi Arabia and Russia are the top two countries with the lowest disruption risk for China, and the other countries are relatively close. However, the reasons for high risk are different. Iraq is mainly due to its country risk and the diplomatic relations with China. Angola is mainly due to the transportation risks. The transportation route passes through the Gulf of Guinea, which is one of the most unsafe maritime transportation nodes. Brazil's risk is mainly due to its low export capacity. What's more, Iran's disruption risk increased significantly in 2011, which was related to the oil embargo imposed by the European Union on Iran in 2012, resulting in Iran's export share from 2012-2015 was significantly lower than the normal level in previous years.

Fig 2 shows the comprehensive risk from different sources, the lower values indicate higher level of comprehensive risks. Compared with the disruption risk, the comprehensive risk has changed significantly, especially in Saudi Arabia and Russia. Due to the large share of exports, the comprehensive risk shows greater volatility and is significantly affected by market fluctuations. In addition, there is greater volatility compared to disruption risk in all countries.

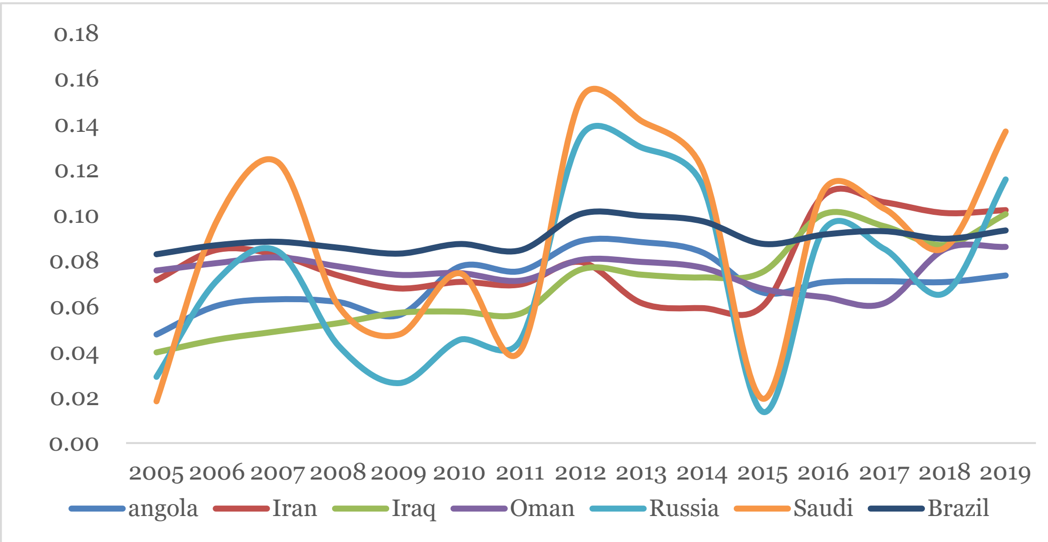

Fig 2. The comprehensive risks of different source

4.2. Desire Import Portfolio

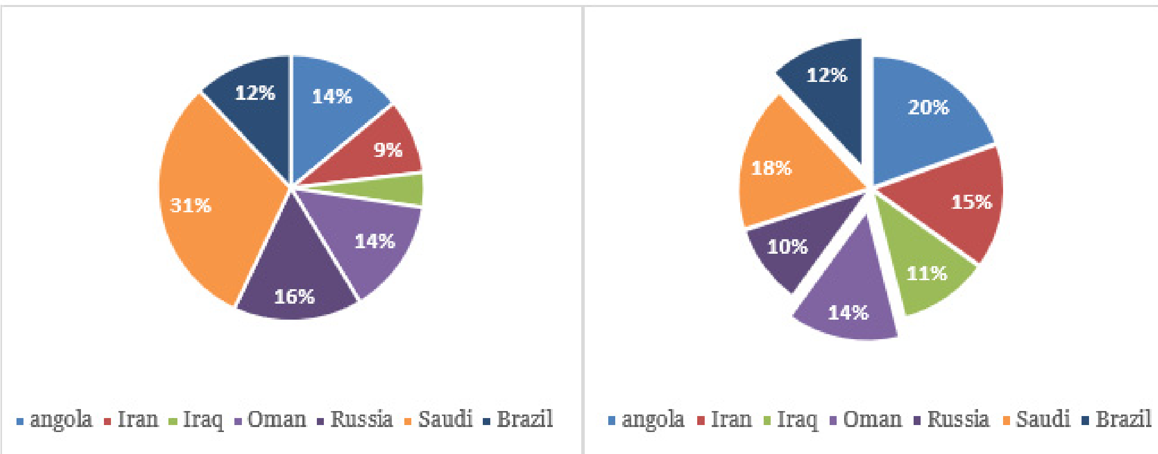

Fig 3. (a) The portfolio optimized by r_1 **Fig 3.** (b) The portfolio optimized by r_2

According to the optimization method introduced in section 2, we optimize the disruption risk and the comprehensive risk respectively, and obtain the optimal import portfolio under the two risks. As shown in Fig 3(a) and Fig 3(b), when only considering the interruption risk, Saudi Arabia is undoubtedly the best import source, its import share is 31%, and Russia ranks second with an import share of 16%. In addition, Iraq has the lowest import share of 4%. When taking comprehensive risk as the optimization object, the import share has changed significantly except Brazil and Oman. Specifically, the import share shift from Saudi Arabia and Russia to Angola and Iraq.

Particularly, for the convenience of calculation, we assume that all of China's oil imports come from these seven countries. The results obtained by the model are not the actual import share, but can indicate the direction of import structure adjustment.

4.3. Comparison of Different Import Portfolios

The main purpose of this section is to answer the question posed by this study: Does it make sense to include market risk in the risk assessment model? We compare the disruption risk and comprehensive risk for two import portfolios.

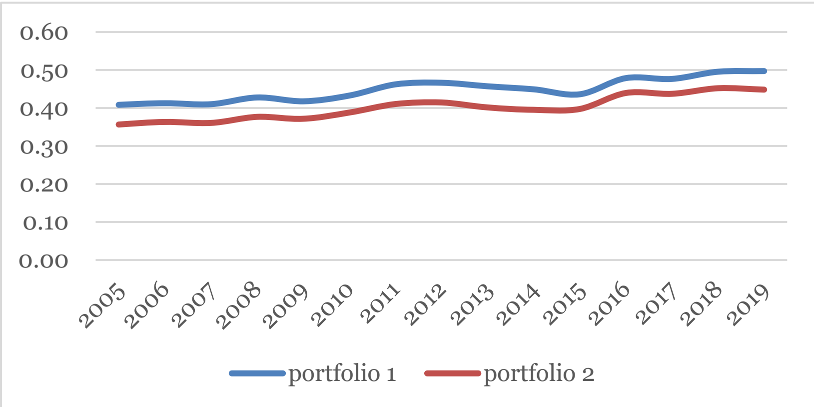

Fig 4. The comparison of disruption risk

Fig 4 shows the comparison of disruption risk. The results show that Portfolio 1 is greater in diversifying risk, the overall disruption risk is lower than Portfolio 2. It means that if China wants to reduce the disruption risk by adjusting its import structure, there is no need to consider the impact of oil price fluctuations.

Fig 5 shows the comparison of comprehensive risk. It can be seen that the risk levels of the two portfolios are very close. However, When the risk appears significant fluctuations in 2007 and 2012, Portfolio 1 shows better with lower risk than Portfolio 2. Combining the two scenarios, we believe that directly optimizing disruption risk is more effective than adding market risk.

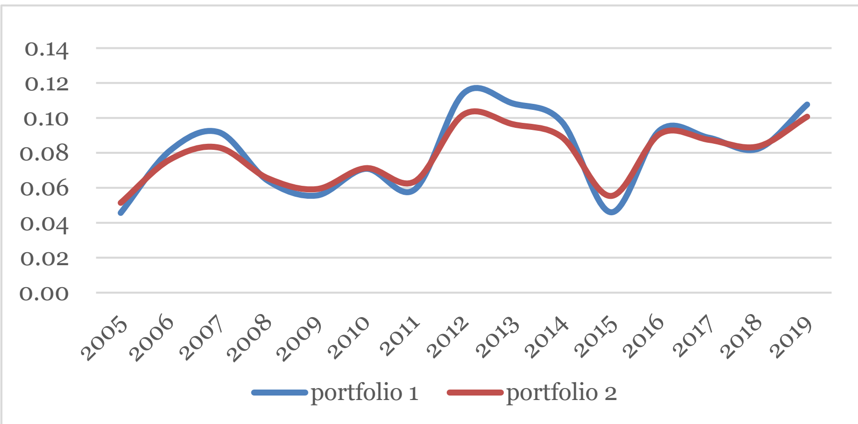

Fig 5. The comparison of comprehensive risk.

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5. Conclusion

Stable energy supply plays an important role in importing country. And a diversified import strategy is a common way to diversify disruption risks. This study proposes a risk measurement model to quantify the disruption risk and comprehensive risk of China's main oil import sources. Secondly, using the Markowitz optimization model, we optimize the import structure with the goal of minimizing disruption risk and minimizing comprehensive risk, respectively. Finally, we compare the differences of risk between the two import portfolios.

The results show that, Saudi Arabia and Russia are the two countries with the lowest disruption risk for China, but when considering systemic risks, due to the large export share, their comprehensive risk shows extreme volatility and the low risk advantage is lost. Therefore, the oil import share also tends to shift from Saudi Arabia and Russia to Angola and Iran.

Comparing the risk values of the two import portfolios, we find that optimizing with the goal of minimizing disruption risk is better in diversify risks. This portfolio has lower risk in disruption risk and comprehensive risk. Therefore, we find that systemic risks cannot be dispersed through the adjustment of import structure. Optimizing disruption risk directly is more effective than adding market risk.

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Appendix: Calculation Detail of the TOPSIS Evaluation Method

Step 1: Data normalization ($\boldsymbol{Z_{ij}}$).

$$\boldsymbol{Z_{ij}} = \boldsymbol{R_{ij}} / \sqrt{\sum_{j=1}^{N} \boldsymbol{R_{ij}^{2}}}, \boldsymbol{i} \in \mathbf{1}, \ldots, \boldsymbol{n};$$

Step 2: Construct weighted norm matrix $\boldsymbol{x_{ij}}$

$$\boldsymbol{x_{ij}} = \boldsymbol{w}^{(j)} * \boldsymbol{Z_{ij}}, \boldsymbol{j} \in \mathbf{1}, \ldots, \boldsymbol{N};$$

Determine ideal and negative ideal solutions

$$\boldsymbol{x_j^*} = \begin{cases} \boldsymbol{max}\{\boldsymbol{x_{ij}}\} \\ \boldsymbol{min}\{\boldsymbol{x_{ij}}\} \end{cases}$$

$$\boldsymbol{x_j^0} = \begin{cases} \boldsymbol{min}\{\boldsymbol{x_{ij}}\} \\ \boldsymbol{max}\{\boldsymbol{x_{ij}}\} \end{cases}$$

Set different indicators into uniform type

$$\boldsymbol{d}^{*(i)} = \sqrt{\sum_{j=1}^{n} (\boldsymbol{x_{ij}} - \boldsymbol{x_j^*})^2}$$

$$\boldsymbol{d}^{0(i)} = \sqrt{\sum_{j=1}^{n} (\boldsymbol{x_{ij}} - \boldsymbol{x_j^0})^2}$$

The comprehensive risk index calculation

$$\boldsymbol{I}^{(i)} = \frac{\boldsymbol{d}^{0(i)}}{(\boldsymbol{d}^{0(i)} + \boldsymbol{d}^{*(i)})}$$